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NASA-16065 (June 2003)
NASA
SUPERSEDING NASA-16065
(March 2003)

NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

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06/03

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SECTION 16065

SECONDARY GROUNDING
06/03

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NOTE: Delete, revise, or add to the text in this section to cover project requirements. Notes are for designer information and will not appear in the final project specification.

This section covers electrical system and equipment grounding including ground rods, grounding conductors, connectors, and other accessories. Section excludes instrumentation and static grounding systems.

Drawings should show plan layout of each grounding electrode, ground mat, ground grid, substation ground bus, interconnecting grounding conductor, and tap connections to steel building columns and outdoor electrical equipment. Detail drawings of ground mats and ground grids should show configuration, ground rod spacings, interconnecting cable and tap connections to substation yard fence, substation ground bus, and interior equipment.

When grounding systems as shown fail to achieve the desired measured resistance to ground, additional ground rods may be required.

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PART 1 GENERAL

1.1 REFERENCES

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NOTE: The following references should not be manually edited except to add new references. References not used in the text will automatically be deleted from this section of the project specification.

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The publications listed below form a part of this section to the extent referenced:

AMERICAN WELDING SOCIETY (AWS)

AWS A5.8	(1992) Specification for Filler Metals for Brazing and Braze Welding

ASTM INTERNATIONAL (ASTM)

ASTM B 3	(2001) Standard Specification for Soft or Annealed Copper Wire

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE Std 81	(1983) Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2002) National Electrical Code

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-STD 889	(Rev B, Notice 2) Dissimilar Metals

UNDERWRITERS LABORATORIES (UL)

UL 467	(1993; 7th Ed) UL Standard for Safety Grounding and Bonding Equipment

1.2 GENERAL REQUIREMENTS

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NOTE: If Section 16003 GENERAL ELECTRICAL PROVISIONS is not included in the project specification, applicable requirements therefrom should be inserted and the first paragraph deleted. If Section 05095 WELDING STEEL CONSTRUCTION is not included in the project specification, applicable requirements therefrom should be inserted and the second paragraph deleted.

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[Section 16003 GENERAL ELECTRICAL PROVISIONS applies to work specified in this section.]

[Section 05095 WELDING STEEL CONSTRUCTION applies to work specified in this section.]

1.3 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01330 SUBMITTAL PROCEDURES and edit the

following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control. Include a columnar list of appropriate products and tests beneath each submittal description.

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The following shall be submitted in accordance with Section 01330 SUBMITTAL PROCEDURES in sufficient detail to show full compliance with the specification:

SD-01 Preconstruction Submittals

Material, equipment, and fixture lists shall be submitted for Grounding Systems including manufacturer's style or catalog numbers, specification and drawing reference numbers, warranty information, and fabrication site information.

SD-02 Shop Drawings

As-Built Drawings shall be submitted in accordance with paragraph entitled, "Drawings," of this section.

SD-03 Product Data

Equipment and performance data shall be submitted for the following items including life, test, system functional flows, safety features, and mechanical automated details.

Manufacturer's catalog data shall also be submitted for the following items:

Ground Rods
Ground Wires
Connectors and Fasteners
Bonding

SD-06 Test Reports

Test Reports shall be submitted for the following tests on grounding systems in accordance with the paragraph entitled, "Field Tests," of this section. Report shall include certified record of ground-resistance tests on each driven ground rod, ground rod assembly, and other grounding electrodes. Record shall include the number of rods driven and their depth at each location to meet the required resistance-to-ground measurements specified. A statement shall be included describing the condition of the soil at the time of measurement.

Bond Resistance Test
Ground Resistance Tests
Ground Isolation Test
Continuity Isolation Test

SD-08 Manufacturer's Instructions

Manufacturer's instructions shall be submitted for the Grounding Systems including special provisions required to install equipment components and system packages. Special notices shall detail impedances, hazards and safety precautions.

1.4 DRAWINGS

As-Built Drawings shall indicate the location of ground rods, mats, grids, building ground bus, supplementary grounding electrodes, steel building columns, and other metal structures connected to the grounding system.

Location of each ground rod and ground-rod assembly and other grounding electrodes shall be identified by letter in alphabetical order and keyed to the record of ground-resistance tests.

PART 2 PRODUCTS

2.1 GROUND RODS

[Ground rods shall conform to the requirements of [NFPA 70] [UL 467] [_____].]

[Ground rods shall be copper-clad steel rods not less than 3/4 inch 20 millimeter in diameter and not less than [10] [_____]-feet [3000] [_____] millimeter long per section. Ground rods shall be clean and smooth and have a cone-shaped point on the first section and shall be die-stamped near the top with the name or trademark of the manufacturer and the length of the rod in feet millimeter.]

2.2 GROUND WIRES

Ground wires shall be in accordance with Section 16145 STANDARD WIRING SYSTEMS.

Ground and bond wires for substations, main panels and distribution points, and ground rod connections shall be annealed bare copper conforming to ASTM B 3, stranded, with 98 percent conductivity. Wire size shall be in accordance with the grounding requirements of NFPA 70.

Ground wires for equipment receptacles for noncurrent carrying hardware, installed in conduit shall be soft drawn copper, in accordance with ASTM B 3, stranded, with green insulation. Wire size shall be as noted.

2.3 CONNECTORS AND FASTENERS

Grounding and bonding fasteners and connectors shall conform to the requirements of UL 467, and Section 16145 STANDARD WIRING SYSTEMS.

Grounding and bonding fasteners shall be [copper] [bronze].

Bonding straps and jumpers shall be copper and shall have a cross-sectional

area of not less than No. 6 AWG 4.12 millimeter diameter (No. 6 AWG). Bonding straps and jumpers for shock-mounted devices with [pivot] [hinged] [swivel] joints shall be made of [flat] [tinned-copper] [woven-wire braid] [flexible stranded] wire.

PART 3 EXECUTION

3.1 BONDING AND GROUNDING

Bonding and grounding requirements shall be in accordance with NFPA 70.

3.2 GROUNDING ELECTRODES

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NOTE: In locations where existing underground utilities, equipment or structures may be damaged, ground rod installation should be accomplished using the water jetting method.

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Grounding electrodes shall include ground rods installed expressly for grounding systems. [Ground rods shall be installed using a water jetting procedure.]

Minimum ground rod section shall be [10] [_____] feet [3000] [_____] millimeter. Sections shall be threaded together and exothermically fusion welded.

[Ground rods shall be installed so that the top of the rod is [4] [_____] inches [100] [_____] millimeter above grade.]

[Ground rods shall be installed so that the top of the rod is not less than [18] [_____] inches [450] [_____] millimeter below finished grade.]

3.3 GROUND GRIDS

Ground grids shall consist of a series of ground rods installed with interconnecting grounding conductors between ground rods. Ground rods shall be spaced as noted.

Ground grid shall be buried not less than [18] [_____] inches [450] [_____] millimeter below the finish grade. Grounding conductors shall be not less than No. [4/0] [_____] AWG [11.7] [_____] millimeter diameter (No. [4/0] [_____] AWG) and shall be exothermically fusion welded together at crossover points and to ground rods.

3.4 BUILDING GROUNDS

Steel framework of the building shall be grounded with a driven ground rod at the base of every corner column and intermediate exterior columns at distances not greater than [60] [_____] -feet [18,000] [_____] millimeter apart. Grounding conductor shall be electrically connected to each ground rod and to each steel column and shall extend around the perimeter of the building. Grounding-conductor loop around the perimeter of the building

shall be not less than No. [4/0] [_____] AWG [11.7] [_____] millimeter diameter (No. [4/0] [_____] AWG). Tap connections from the ground loop to the building steel shall be not less than No. [4/0] [_____] AWG [11.7] [_____] millimeter diameter (No. [4/0] [_____] AWG).

Building ground shall be buried not less than 18 inches 450 millimeter below grade and [2] [_____] feet[600] [_____] millimeter from the building foundation. Interconnecting grounding conductor between ground grid and building grounds shall be not less than No. [4/0] [_____] AWG [11.7] [_____] millimeter diameter (No. [4/0] [_____] AWG).

3.5 EQUIPMENT GROUNDING

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NOTE: This paragraph specifies a "Case" ground. A Case ground is where grounding is critical such as fueling areas, pads, etc. A modification such as an office building or an administrative area would not require the additional ground.

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[In addition to the green colored equipment grounding conductor required in each raceway and sized in accordance with Table 250.122 of the NEC, each panelboard/ switchboard enclosure, transformer housing, motor housing, disconnect, starter, and other electrical equipment, addressed under this contract, shall be bonded to the grounding system with a stranded copper conductor, routed external to the feeder raceway.]

Metallic raceway systems shall have electrical continuity with equipment individually and directly connected to the building ground, independent of the raceway system.

Enclosures for panelboards shall be individually and directly connected to the building ground. Grounding conductor shall be not less than No. [2] [_____] AWG [6.54] [_____] millimeter diameter (No. [2] [_____] AWG) and shall be connected from the building ground to a copper ground-bus terminal strip located in each panelboard.

Polarized receptacles, lighting fixtures, and equipment enclosures shall be grounded with an identified (green color) insulated conductor, not smaller than No. [12] [_____] AWG [2.03] [_____] millimeter diameter (No. [12] [_____] AWG), connected to the branch circuit ground-bus terminal strip. Ground-bus terminal strip in each panelboard enclosure shall be isolated and independent of the system neutral terminal strip.

Indoor substations, transformers, switchboard frames, switchgear assemblies, motors, motor control centers, air compressors, air handlers, refrigerated air dryers, generators, frames and tracks of cranes, and [_____] shall be individually and directly connected and grounded to the building ground. Current-carrying capacity of the grounding conductor shall be the same as the current-carrying capacity of the power conductors for circuits utilizing power lines size No. [2] [_____] AWG [6.54] [_____] millimeter diameter (No. [2] [_____] AWG) and smaller. For circuits with power wiring larger than No. [2] [_____] AWG [6.54] [_____] millimeter

diameter (No. [2] [_____] AWG), the grounding conductor shall be in accordance with NFPA 70, except that the grounding conductor shall be not smaller than No. [2] [_____] AWG [6.54] [_____] millimeter diameter (No. [2] [_____] AWG).

Noncurrent carrying metallic parts of electrical equipment, including metallic cable sheaths, conduit, raceways, and electrical structural members, shall be bonded together and connected to the ground grid or ground connection rods.

Secure ground systems shall be installed for power and instrumentation. Each system shall be independently connected to the building counterpoise as shown.

Secure ground systems shall consist of unspliced ground wires in individual welded or epoxied conduit runs from the secure area to the building counterpoise. Welding and epoxying shall conform to Section 16145 STANDARD WIRING SYSTEMS.

3.6 GROUNDING CONNECTIONS

Ground connections shall be bonded connections in accordance with paragraph entitled, "Bonding."

Ground connections that are buried or in inaccessible locations shall be [welded] [silver-soldered].

Connections in accessible locations shall be bolted. Connections to steel building columns in accessible locations shall be cast-copper-alloy clamp lugs [bolted] [exothermically fusion-welded] to the structure.

Ground connection surfaces shall be cleaned and greased and foreign matter removed. Clad material shall not be penetrated in the cleaning process. Connection shall be made between like metals where possible. Where dissimilar metals are welded, brazed, or clamped, the weld kit manufacturer's instructions shall be followed. Connections between dissimilar metals shall not produce galvanic action in accordance with MIL-STD 889.

3.7 BONDING

3.7.1 Type of Bonds

Bonding of metal surfaces shall be accomplished by [brazing] [welding] [clamping] [structural joining methods].

3.7.1.1 Brazing

Brazing solder shall conform to AWS A5.8 [_____].

3.7.1.2 Welding

Welding shall be by the exothermic process. Welding procedure shall include the proper mold and powder charge and shall conform to the

manufacturer's recommendations.

Welding processes shall be of the exothermic fusion type that will make a connection without corroding or loosening. Process shall join all strands and shall not cause the parts to be damaged or weakened. Completed connection or joint shall be equal or larger in size than the conductors joined and shall have the same current-carrying capacity as the largest conductor. Buried ground connections shall be painted with a bitumastic paint.

3.7.1.3 Clamping

In external locations, clamping shall be used only where a disconnect type of connection is required. Connection device may utilize [spring-loaded jaws] [threaded fasteners]. Device shall be constructed such that positive contact pressure shall be maintained at all times. Machine bolts with [tooth-type] [spring-type] lockwashers shall be used.

3.7.1.4 Structural Joining Methods

Joints made with high-strength structural bolts, and clean unpainted faying surfaces shall be considered sufficiently bonded. A jumper shall be installed across the joint in the form of a No. [4] [_____] AWG [5.19] [_____] millimeter diameter (No. [4] [_____] AWG) bare copper wire [exothermically welded] [bond welded with a 1/4-inch 7 millimeter or larger fillet weld, with a [2] [_____]-inch [50] [_____] millimeter minimum length across the connection] at each end to the surfaces involved spanning the connection wire jumpers shall be used across joints employing miscellaneous machine bolts.

3.7.2 Cleaning of Bonding Surfaces

Surfaces that comprise the bond shall be thoroughly cleaned before joining. An appropriate abrasive shall be applied with a gentle and uniform pressure to ensure a smooth and uniform surface. Excessive metal shall not be removed from the surface. Clad metals shall be cleaned in such a manner that the cladding material is not penetrated by the cleaning process. Bare metal shall then be cleaned with an appropriate solvent to remove any grease, oil, dirt, corrosion preventives, and other contaminants. Bond to the cleaned area shall be made within one hour after cleaning. Joint shall be sealed and the exposed surfaces refinished within two hours of exposure to prevent oxidation. When additional time is required, a corrosion preventive compound shall be applied until the area can be refinished.

3.7.3 Bonding Straps and Jumpers

Jumpers shall be installed such that the vibration by the shock-mounted device shall not change its electrical characteristics.

Bonds shall be [brazed] [welded] for outdoor locations unless a disconnect type of connection is required. When a disconnect is required, clamping with bolts shall be used. A tooth-type lockwasher shall be inserted between the strap and metallic member for each bolt.

Straps shall be bonded directly to the basic structure and shall not penetrate any adjacent parts. Straps shall be installed in an area that is accessible for maintenance.

Single straps shall be used for the bonds and shall be installed such that they will not restrict movement of structural members. Two or more straps shall not be connected in series.

Straps shall be installed such that they will not weaken structural members to which they are attached.

3.7.4 Equipment and Enclosure Bonding

Each metallic enclosure and all electrical equipment shall be bonded to ground. At least one copper connection shall be made from the system ground point to one or more enclosures in the area such that all enclosures and equipment provide a low-impedance path to ground when properly bonded together.

3.7.5 Bonding of Conduit and Raceway Systems

Bond all metal conduit, fittings, junction boxes, outlet boxes, armored and metal sheathed cable, and other raceways. Care shall be taken to ensure adequate electrical contact at the joints and terminations.

3.7.5.1 Rigid Metal Conduit and Terminations

Threaded connections must be wrench-tight and there shall be no exposed threads. All ends of the conduit shall be reamed to remove burrs and rough edges. Conduits entering boxes and enclosures shall be bonded to the box with [bonding-type locknuts, one outside and one inside.] [locknuts and grounding-type bushings.] Locknuts that gouge into the metal box when tightened are not acceptable.

Conduit systems that are interrupted by PVC dielectric links shall be bonded separately on either side of the link. Dielectric link shall not be jumpered.

3.7.5.2 Flexible Metal Conduit

Flexible conduit shall have an integral grounding conductor.

3.7.6 Cable Tray Bonding

Cable tray sections shall be bonded together. Cable tray sections in tandem assembly shall be considered as having electrical continuity when these sections are bonded with the appropriate bolts. Bond straps shall be installed across expansion joints. Cable trays shall be bonded to the building ground system.

3.7.7 Protection of Finished Bonds

Finished bonds shall be protected by painting to match the original finish after the bond is made.

3.8 FIELD TESTS

The following tests shall be performed by the Contractor in the presence of the Contracting Officer.

3.8.1 Bond Resistance Test

Resistance of any bond connection shall not exceed [0.5] [_____] milliohm. Bonds that exceed this resistance shall be reworked by the Contractor at no additional cost to the Government.

3.8.2 Ground Resistance Tests

Grounding systems shall be tested for ground resistance. Total resistance from any point on the ground network to the building counterpoise shall not exceed [50] [_____] milliohms.

Ground resistance and counterpoise tests shall be made during dry weather, and no sooner than [48] [_____] hours after rainfall. Tests shall be conducted using the ratio method that measures the ratio of the resistance to earth of an auxiliary test electrode to the series resistance of the electrode under test and a second auxiliary electrode. Measurements shall be performed in accordance with IEEE Std 81.

Indicating instrument shall be self-contained and shall include a direct-current generator, synchronized current and potential reversers, crossed-current and potential coils, direct-reading ohmmeter, series resistors, and range-selector switch. Direct-reading ohmmeter shall be calibrated for ranges of 0 to 20 ohms and 0 to 200 ohms.

Auxiliary grounding electrodes shall be placed in accordance with instrument manufacturer's recommendations but not less than [50] [_____] feet [15,000] [_____] millimeter apart, in accordance with IEEE Std 81.

3.8.3 Ground Isolation Test

Ground systems shall be tested for isolation from other ground systems.

3.8.4 Continuity Isolation Test

Continuity test shall be performed on all power receptacles to ensure that the ground terminals are properly grounded to the facility ground system.

-- End of Section --